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PRESENTATION OUTLINE

Anadromous fishes – challenges for management

- Overview of stock structure techniques
 - historical methods and limitations
 - advantages of molecular markers

- Microsatellites general overview
- Alewife and blueback herring population genetic stock structure across the US portion of the species' ranges

ANADROMOUS FISHES

 Spend the majority of their lives in the ocean but return to freshwater habitats to spawn

- Ecologically and economically valuable:
 - ecosystem linkages (marine freshwater terrestrial)
 - support important fisheries

 Requires management across multiple habitats





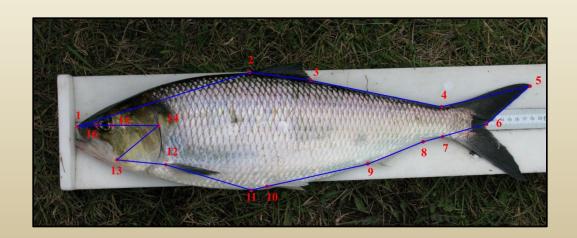
MANAGEMENT CHALLENGE

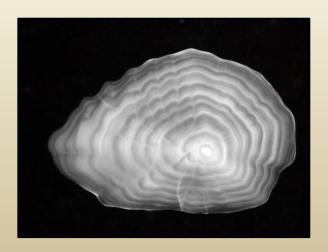
- Lengthy ocean migrations typically mixed population assemblages:
 - long range dispersal and extensive gene flow
- Spawning/rearing in freshwater:
 - philopatry and establishment of distinguishable group
 - variable among species (broad to fine spatial scale)
- Effective management requires identifying discrete units (stocks and populations)



STOCK STRUCTURE TECHNIQUES

- Historically used variation in traits or natural tags that were specific to spawning aggregations:
 - growth patterns
 - body morphology (Melvin et al. 1992)
 - elemental composition of hard parts (Walther et al. 2008)
- Limitations: plasticity and the influence of environmental variation

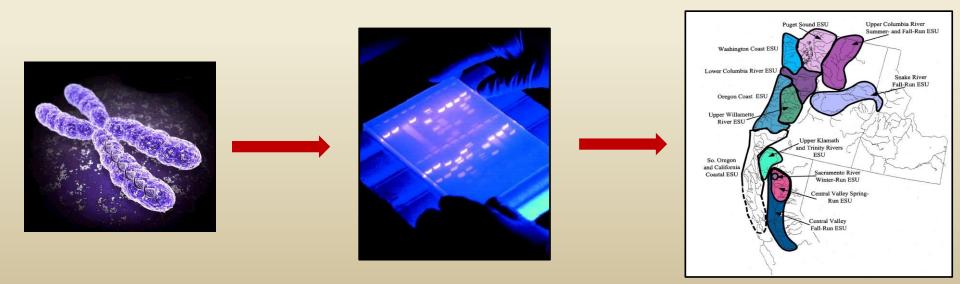




NEED TO INCORPORATE 'CONNECTIVITY'

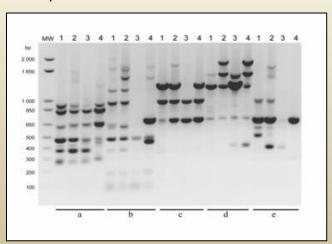
 Molecular markers emphasize reproductive cohesion (i.e., evolutionary paradigm; Waples and Gaggiotti 2006)

- Factor prominently in defining populations and designating stock boundaries
 - improved resolution for management



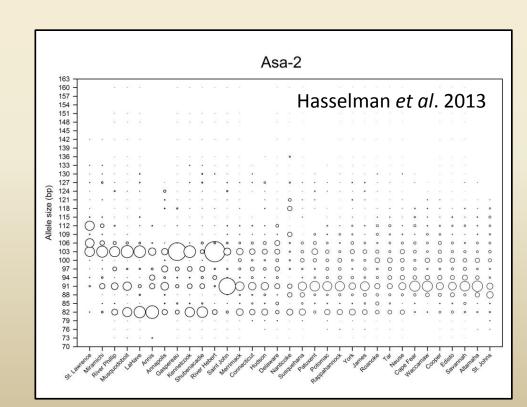
MICROSATELLITES

- Tandem arrays of short DNA repeats (2-6 bp)
- Abundant throughout eukaryote genome
 - selectively neutral (no effect on fitness)
- Co-dominant (bi-parental inheritance 2 alleles)
 - allow identification of genotypes as size of PCR product
- Highly polymorphic via gain/loss of repeat units:
 - allele 1: CCGTAGCATCATCATCATGGCT → (CAT)₅
 - allele 2: CCGTAGCATCATCATCAAGGCT → (CAT)₄



ALLELE FREQUENCIES

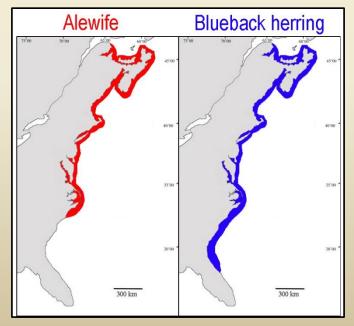
- Examine variation in allele frequencies to determine:
 - amount of genetic diversity (H_O, A_R)
 - relationships among populations (NJ tree, PCoA)
 - amount of differentiation (F_{ST})
 - number of genetically distinguishable groups (STRUCTURE)
 - spatial scale of population structure (IBD)
 - stock boundaries



ALEWIFE AND BLUEBACK HERRING

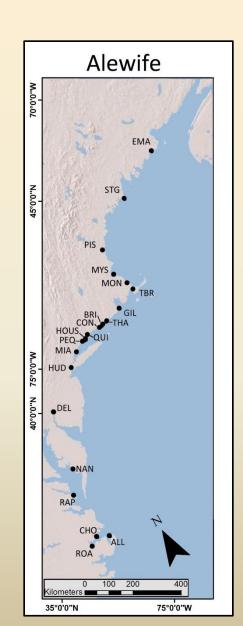
- Anadromous; broad geographic ranges
 - mixed marine aggregations
 - philopatry; genetically distinguishable
- Landings declined by 93% since 1970
- ESA petition (2011) required information on population genetic structure
 - identification of Distinct Population Segments (DPS)

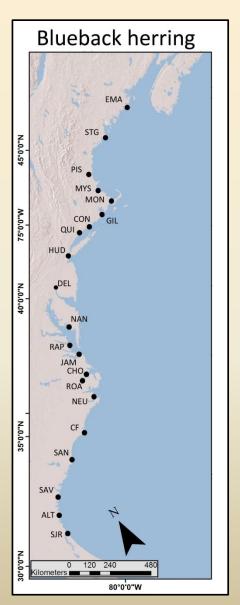




SAMPLING AND GENOTYPING

- See Palkovacs et al. (2014)
- Alewife:
 - 20 populations
 - Maine to North Carolina
 - N=947
- Blueback herring:
 - 20 populations
 - Maine to Florida
 - N=1183
- Both species genotyped across same 15 microsatellites





DATA ANALYSES

Pairwise genetic differentiation (F_{ST})

- Population structure (Bayesian clustering STRUCTURE)
 - stock designations

Principal Coordinates analysis (PCoA – genetic

distance; D_A)

Isolation by distance

GENETIC DIFFERENTIATION

• Alewife:

- weak to moderate genetic differentiation across US range
- F_{ST} = 0.049; range=0.000-0.148

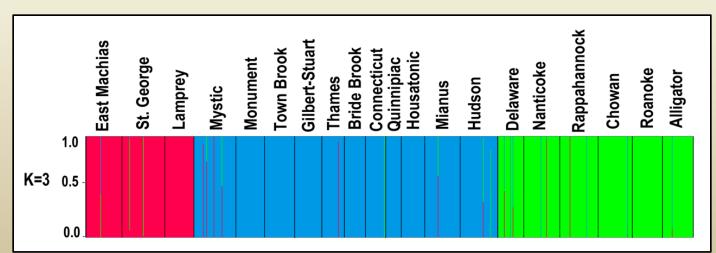


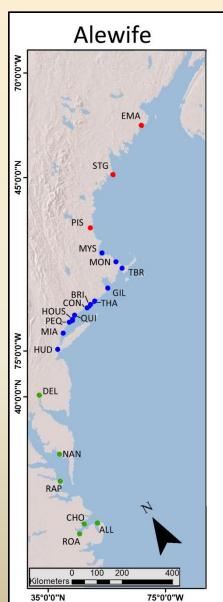
Blueback herring:

- weak genetic differentiation across US range
- F_{ST} = 0.030; range=0.000-0.106
- For both species non-significant (P>0.05) differences found primarily among neighboring and geographically proximal populations

ALEWIFE STOCK STRUCTURE

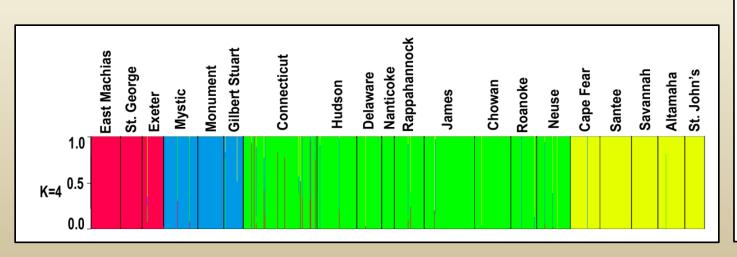
- Bayesian clustering identified K=3 as the most likely number of genetically distinguishable clusters (stocks):
 - Northern New England (•)
 - Southern New England (•)
 - Mid-Atlantic (•)

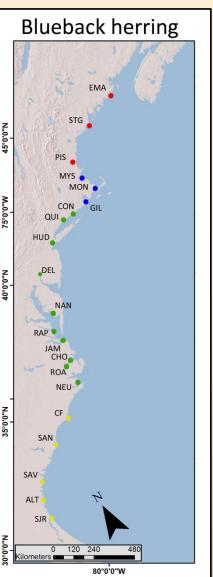




BLUEBACK HERRING STOCK STRUCTURE

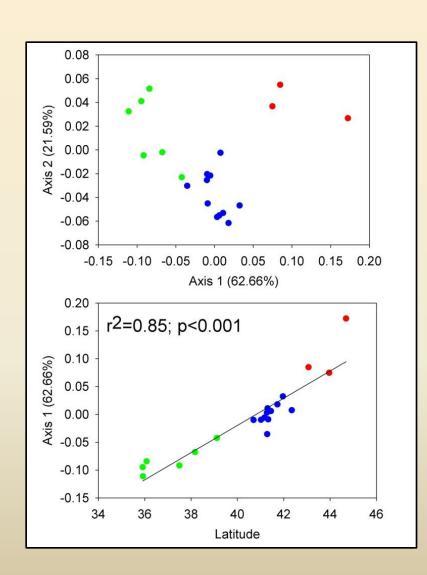
- Bayesian clustering identified K=4 as the most likely number of genetically distinguishable clusters (stocks):
 - Northern New England (•)
 - Southern New England (•)
 - Mid-Atlantic (•)
 - South Atlantic ()





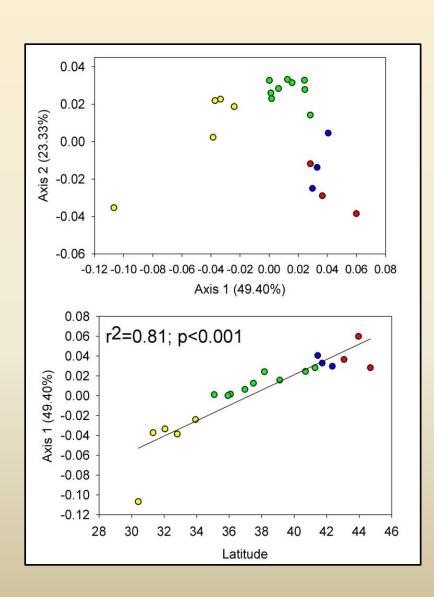
ALEWIFE - PCOA

- Three factors explained 92% of variation in genetic distance among populations
- Axis 1 exhibited a significant linear relationship with latitude
- These results suggest a strong spatial component to genetic structure in alewife



BLUEBACK HERRING - PCOA

- Three factors explained 85% of variation in genetic distance among populations
- Axis 1 exhibited a significant linear relationship with latitude
- These results suggest a strong spatial component to genetic structure in blueback herring



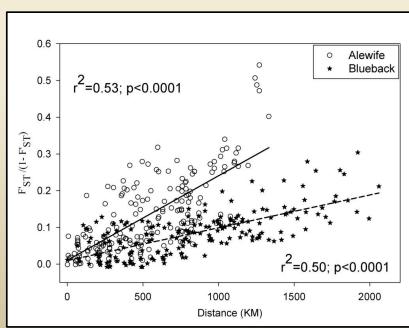
SPATIAL PATTERN OF GENETIC STRUCTURE

- Mantel test: significant IBD pattern for both species
 - increased genetic differentiation with geographic distance
 - stronger for alewife

Stepping stone model of population structure (Kimura and Weiss

1964):

 gene flow more likely among geographically proximal population



SUMMARY

- Microsatellites comprise natural tags that encapsulate elements of reproductive cohesion and are useful for defining populations and designating stock boundaries
- Alewife: 3 stocks; Blueback herring: 4 stocks
 - Bayesian clustering methods are 'conservative'
 - differences in allele frequencies are more accurate
 - Strong spatial component to river herring genetic structure
 - River based management is most appropriate



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- 1. Melvin GD, Dadswell MJ, and McKenzie JA (1992). Usefulness of meristic and morphometric characters in discriminating populations of American shad (*Alosa sapidissima*) (Ostreichthyes, Clupeidae) inhabiting a marine-environment. Canadian Journal of Fisheries and Aquatic Sciences 49: 266-280.
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- 4. Hasselman DJ, Ricard D, Bentzen P (2013). Genetic diversity and differentiation in a wide ranging anadromous fish, American shad (*Alosa sapidissima*), is correlated with latitude. *Molecular Ecology* 22(6): 1558-1573.
- 5. Palkovacs EP, Hasselman DJ, Argo EE, Gephard SR, Limburg KE, Post DM, Schultz TF, Willis TV (2014). Combining genetic and demographic information to prioritize conservation efforts for anadromous alewife and blueback herring. Evolutionary Application 7: 212-226.
- 6. Kimura M and Weiss GH (1964). The stepping stone model of population structure and the decrease of genetic correlation with distance. Genetics 49(4): 561-576.